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The Micro Slit Gas Detector

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Abstract

We describe the first tests with a new proportional gas detector. Its geometry consists in slits opened in a copper metallized kapton foil with 30 μm anode strips suspended in these openings. In this way the multiplication process is similar to a standard MSGC. The fundamental difference is the absence of an insulating substrate around the anode. Also the material budget is significantly reduced, and the problems related to charging-up or polarization are removed. Ageing properties of this detector are under study.

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1 Introduction

A new generation of high rate proportional gaseous detectors based on advanced printed circuit technology (PCB) has been introduced during the last year. Important efforts in the research and development of these kind of detectors are justified because of their low cost and robustness. Examples of these detectors are the Gas Electron Multiplier (GEM) [1], the Micro-Groove Detector (MGD) [2], and the WELL detector [3]. They have in common the use of thin kapton foils and PCB techniques in order to implement the multiplication structure. The flexibility of the readout is precisely another advantage of these detectors, allowing in some cases an intrinsic two dimensional device. Detector charging up and operation stability are important issues that need to be studied. We present here indications of a good performance for the Micro Slit Gas Detector (MSGD).

2 Detector description

The development of kapton etching techniques (commonly used for GEM production) has made possible the easy construction of new detector geometries.

In this case one of the metallic layers, of a 50 μm thick kapton foil copper clad on both sides, is litographically etched with a matrix of rectangular round-corner slits, 105 μm wide and 6 mm long (repeated in the transverse direction with a period of 200 μm). In the opposite side, a pattern 30 μm wide strips with 200 μm pitch is etched, ensuring that the strips run along the slits (see Figure 1).

When kapton is removed, the final device has 30 μm strips suspended only by 200 μm kapton joints regularly spaced at 8 mm (to provide mechanical stiffness) (Figure 2). In this way a "substrate-free" MSGC is achieved, and the detector resembles a wire-chamber.

The first detector prototype, 10×10 cm^2, was enclosed in a gas volume, which was sealed symmetrically by two thin conductive foils, at 3 mm distance from the kapton plane (see Figure 3). The first provides the drift field towards the multiplication region (drift plane), and the second was given, in the test, a certain potencial with respect to the anodes, which we discuss later. Initially this backplane was metallized with the aim to define better

the electric field around the anode.

3 Detector performance

The signal development takes place in a similar way as in a standard MSGC. Drifting electrons reach the E-field region between anode and cathode, and are then multiplied inside the rectangular slits. The electron avalanche produced in this region is collected by the anode strips. The ion charge is collected by the cathode and the drifting plane, in a proportion depending on the operating voltages. In this case anodes were grounded through a bias resistor while a negative potential was applied to the cathode.

The detector was irradiated with X rays coming from an Cr X-ray tube and the gas mixture used was composed by Ar and DME in different proportions.

The signal was extracted from an OR of 32 anodes and amplified by a ORTEC 142PC preamplifier followed by an AFT Research Amplifier Model 2025. The output was digitized in a Tektronix TDS 684A Oscilloscope.

3.1 Operation voltages

Typical operating voltages in the first prototype are very similar to MSGCs. Detector gains obtained are somewhat lower[3] . This is understandable due to the width of the anode strips (still limited by the PCB production technique), and also as a consequence of the extended gap between anode and cathode because of the non planar geometry and the cathode width [4]. The detector gain exhibits an exponential dependence on the voltage applied to the cathode (Figure 4). In this Figure the maximum gains showed were limited by sparks in the chamber. In some tests afterwards the MSGD was exposed to severe sparking during hours but no damage in its structure was found.

A pulse height spectrum can be seen in Figure 5. The voltage applied to the backplane does not affect essentially the anode signal, as illustrated also in Figure 5.

[3]In a typical MSGC with 10 μm anodes and 100 μm cathodes with Ar-DME 50% a gain of aprox. 1000 is achieved with a cathode potential of 550, while in the Micro Slit detector gain is around 600.

[4]New prototypes are under development with wider cathodes

Figure 6 shows spectra obtained with different values of the cathode voltage. Decreasing it by 10 V, for the drift voltage V_d=-1600 V, produces a 20% drop in the gain.

In these spectra, the Argon scape peak is clearly separated from that corresponding to the K_α photon energy at 5.4 KeV. The energy resolution for pulse height spectra measured with V_d=-1500 V and V_{cat}=-515 V is 16% FWHM, and in this field configuration 90% of the ions drift to the cathode electrode.

The dependence of the gain with the cathode voltage was also studied for different gas mixtures. The results of these studies (Figure 4) show that the highest gains were obtained with high argon content in the gas mixture.

Also the dependence on gain with the drift field is showed in Figure 7. Clearly an enhancement of gain is obtained with higher drift field values.

3.2 Short term gain variation

Typically variations on the gain during the first operation moments manifest in those detectors using insulating substrates. This is due to the accumulation of charge on the dielectric (charging-up) and polarization, producing electric field modifications, and thus affecting the amplification process. Normally this effect has been avoided using higher conductive coatings (like LPVD diamond) [4] or substrates (like S8900). In the GEM, for example, kapton surface of the holes is clearly traversed by the dipole electric field thus producing some charging up [5]. In this geometry we have designed the electrodes in such a way that exposed area to E-field represents only around 1% of the total. This (see below) represents a major improvement in this type of devices just simplifying the production (no coating needed).

The effect of charging up on the MSGD gain was determined by registering the pulse height spectrum and comparing the maxima from consecutive periods. Figure 8 shows the evolution of the gain during the first 82 minutes of irradiation under a rate of 10^3 Hz mm^2 beginning from a cold start (detector and beam initially switched off). Variations of the gain are less than a 4%.

In order to accelerate the effect of this possible charge accumulation, the

[5] A small admixture of water in the gas as well as straighter holes have demonstrated to solve the problem.

MSGD was irradiated with a photon rate of $\approx 10^6$ during about 10 minutes. Figure 9 compares the spectra before and after the high irradiation. No appreciable change occurs. This behaviour differs from that observed in detectors with dielectric substrate, like standard MSGC or GEM.

4 Rate capability

The rate capability of this detector was determined by measuring the current in the group of instrumented anodes for different values of the incident photon flux. Driving the X-ray tube to its maximum current, we could reach up to 2.6 $\times 10^6$ Hz mm^{-2} incident photon flux, collimated over a surface of 3 mm^2. No appreciable drop in gain was observed. In Figure 10 the relative changes in the detector gain during the irradiation test are shown. They were determined from the observed deviations with respect to a linear fit between X-ray intensity and anode current.

The advantage of the MSGD is the effective absence of any dielectric surface, avoiding the use of delicate high resistive coatings to reach values of 10^6 mm^{-2} s^{-1}.

5 Conclusions

A prototype of a new proportional gas detector, based on the PCB technology, has been designed and tested.

The first tests with this detector show important properties, related mainly to its high rate capability (up to 2.5 MHz mm^{-2}) and the absence of charging up effects.

In spite of its similarity to the MSGC in the amplification process the use of the PCB technology reduces considerably the cost and material budget. Besides, it is important to remark the supression of the substrate for supporting the anode structure.

Another interesting possibility is to set up a similar detector with a mirror cathode structure respect to the anode plane, thus having upper and lower drift regions and allowing to reduce the effective drift gap and charge collection time.

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[2] R. Bellazzini, et al, **The Micro-Groove Detector** (May 25, 1998), submitted for publication in NIM.

[3] R. Bellazzini, et al, **The WELL Detector** (May 25, 1998), submitted for publication in NIM.

[4] A. Barr, et al, **"Diamond" over-coated Microstrip Gas Chambers for high rate irradiation**, CERN-PPE-96-021.

Figure Captions

Figure 1: Copper clad kapton design of the Micro Slit Gas Detector (top view).
Figure 2: Scheme of one slit (transverse section). The copper layer is 15 μm thick.
Figure 3: Schematic view of the tested prototype.
Figure 4: Behaviour of the gain as a function of the cathode voltage for different gas mixtures.
Figure 5: Pulse height spectra obtained with different values of the voltage in the backplane.
Figure 6: Effect of the cathode voltage in the response of the detector.
Figure 7: Gain dependence with the drift field.
Figure 8: Evolution of the gain during the first irradiation moments.
Figure 9: Pulse height spectra before and after high irradiation.
Figure 10: Rate capability of the Micro Slit Gas Detector.

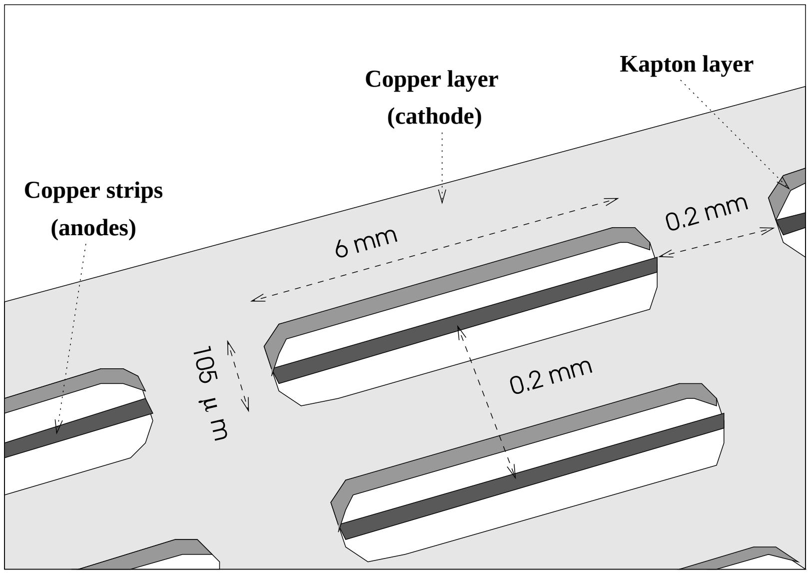


Figure 1

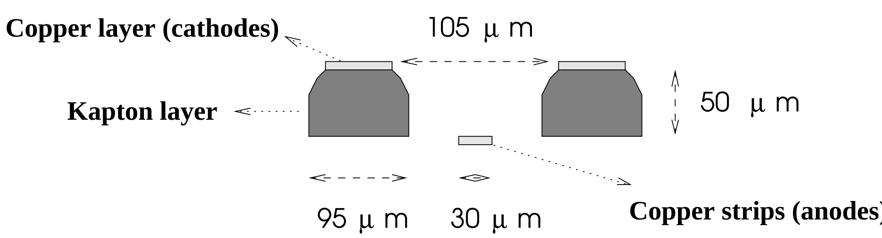


Figure 2

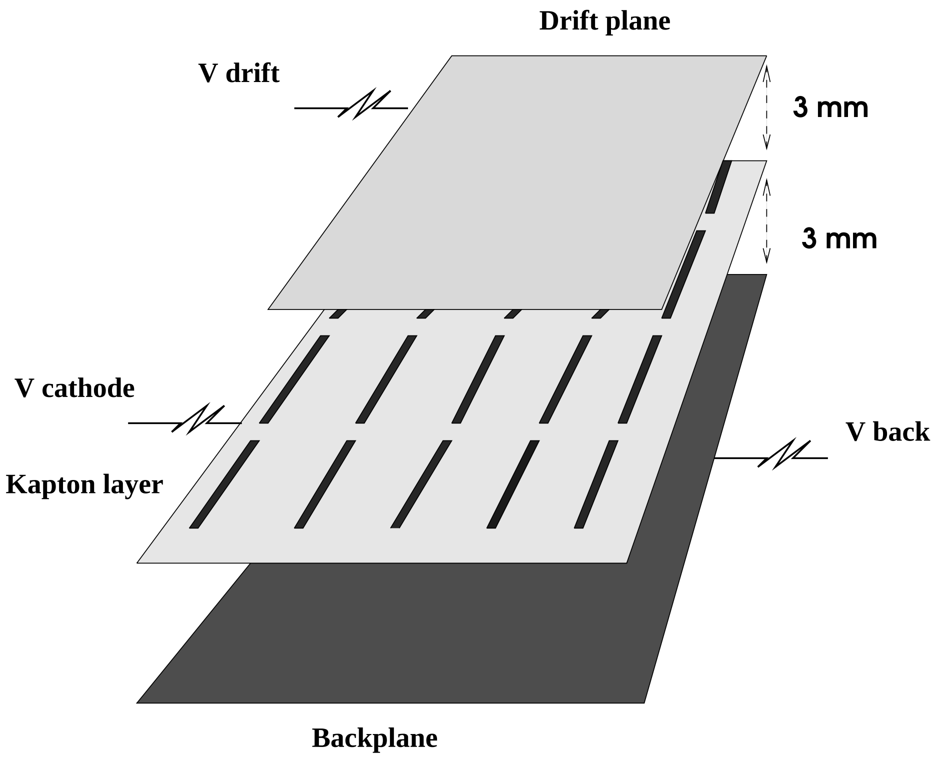

Drift plane
V drift
3 mm
3 mm
V cathode
V back
Kapton layer
Backplane

Figure 3

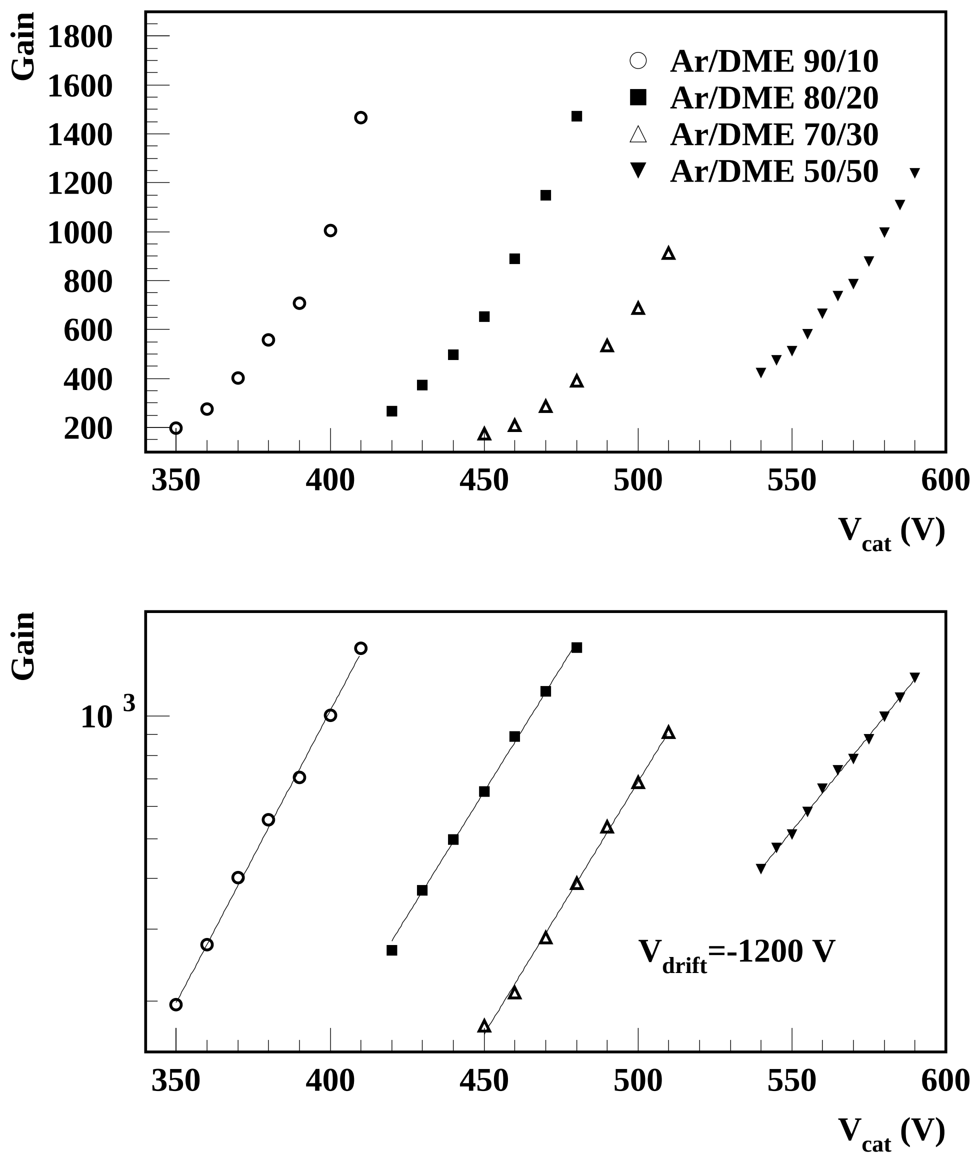

Gain
1800
1600
1400
1200
1000
800
600
400
200
Ar/DME 90/10
Ar/DME 80/20
Ar/DME 70/30
Ar/DME 50/50
350
400
450
500
550
600
V_{cat} (V)
Gain
10^3
V_{drift}=-1200 V
350
400
450
500
550
600
V_{cat} (V)

Figure 4

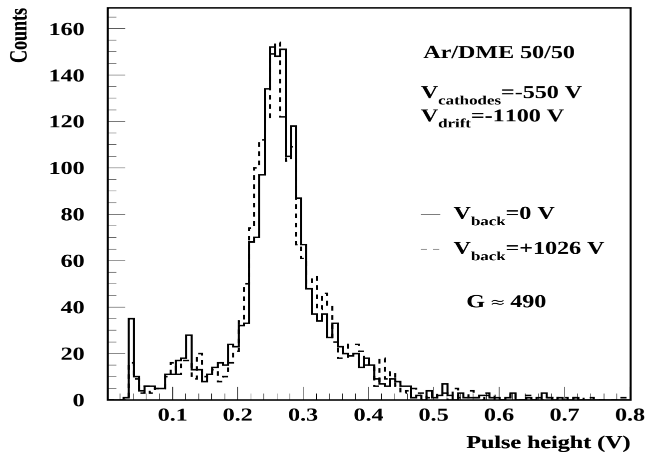


Figure 5

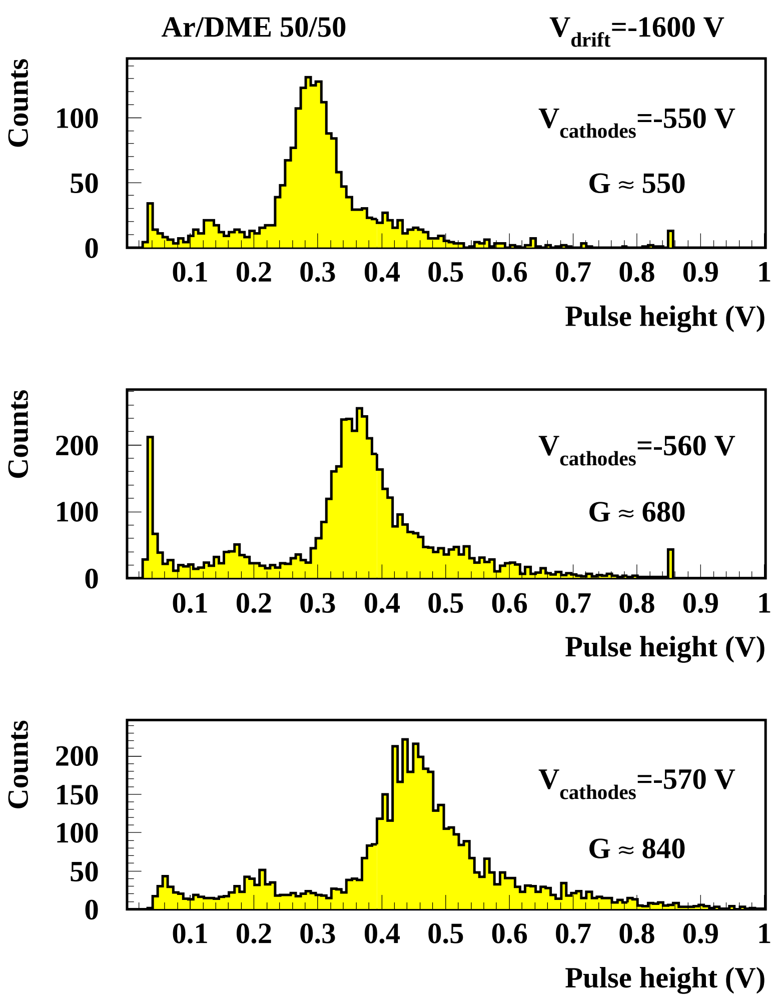
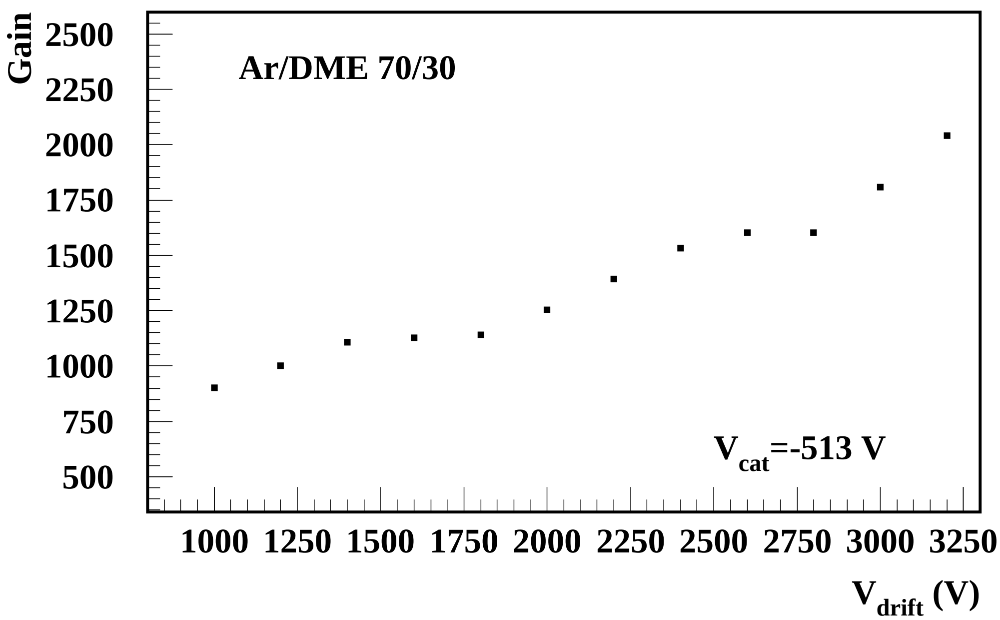
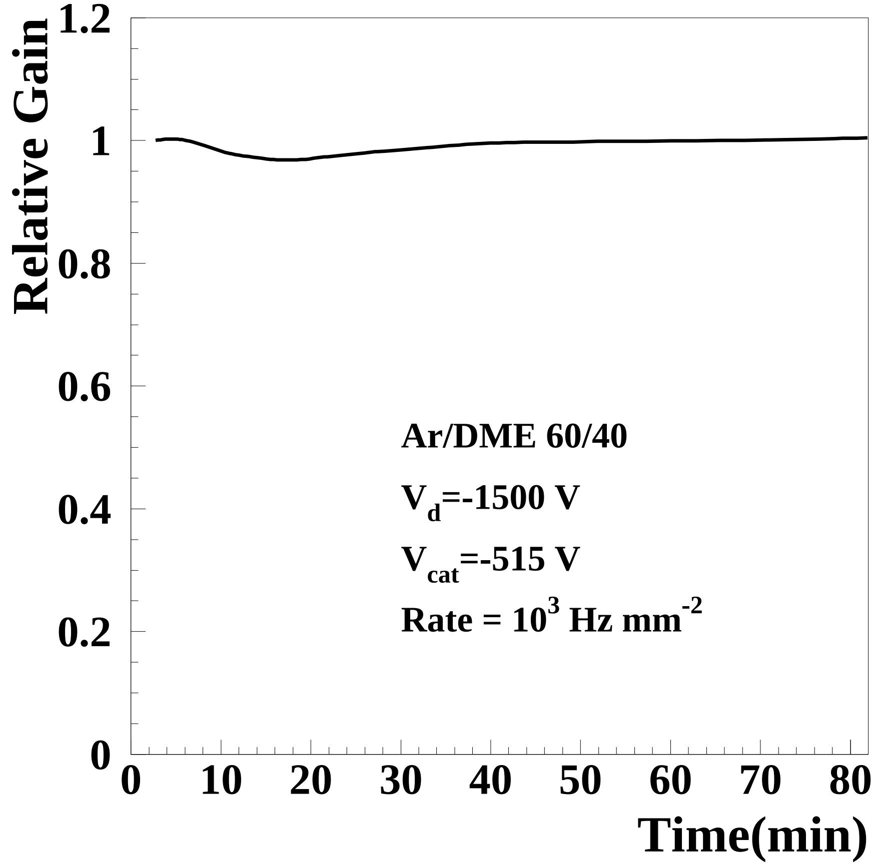


Figure 6



Gain
2500
2250
2000
1750
1500
1250
1000
750
500
Ar/DME 70/30
V_{cat}=-513 V
1000 1250 1500 1750 2000 2250 2500 2750 3000 3250
V_{drift} (V)

Figure 7



Relative Gain
1.2
1
0.8
0.6
0.4
0.2
0
Ar/DME 60/40
V_d=-1500 V
V_{cat}=-515 V
Rate = 10^3 Hz mm^{-2}
0 10 20 30 40 50 60 70 80
Time(min)

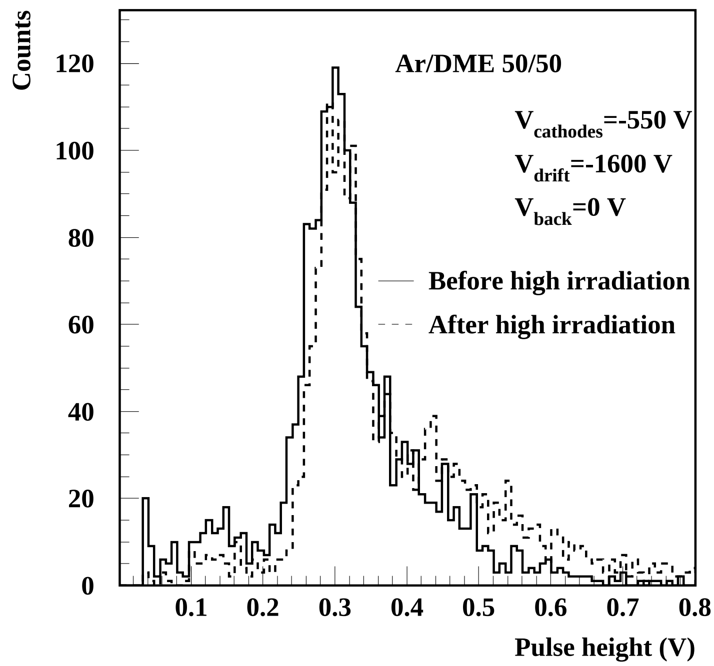
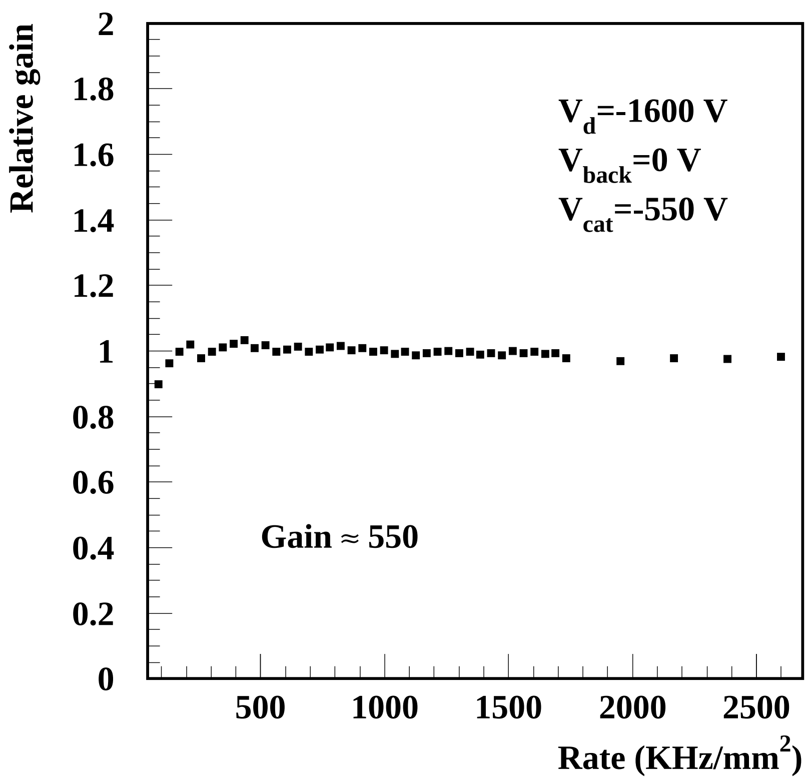

Counts
120
100
80
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Pulse height (V)
Ar/DME 50/50
$V_{cathodes}$=-550 V
V_{drift}=-1600 V
V_{back}=0 V
Before high irradiation
After high irradiation

Figure 9


Relative gain
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500
1000
1500
2000
2500
Rate (KHz/mm^2)
V_d=-1600 V
V_{back}=0 V
V_{cat}=-550 V
Gain ≈ 550